The drawings have been amended as required by the Examiner. Corrected formal drawings will be filed upon allowance of the Application.

Claim 1 has been amended to clarify the invention and to distinguish the invention from the prior art. More particularly, claim 1 has been amended to specify that the etching step leaves the metal silicide layer intact, and to include, after the etching step, a second heat-treating step. Claims 2-5 have been added to further scope the invention, and find support on pages 4, 6 and 7 of the specification.

Pursuant to 37 CFR 1.121, marked copies of the amended specification paragraphs and amended claims showing the changes made therein accompany this Amendment.

The art rejection is respectfully traversed. In rejecting claim 1 as obvious from Suguro (U.S. Patent No. 6,033,537) in view of Lee et al. (U.S. Patent No. 6,074,960), the Examiner acknowledges the primary reference Suguro fails to specify the claimed etching solution or etching time. As pointed in Applicant's specification, the claimed etching solution and etching time are critical to the successful practice of the present invention in order to remove unreacted or partially oxidized cobalt while leaving the metal silicide layer intact. (See, for example, the paragraph bridging pages 5-6 of the specification.) In other words, the choice of the etching solution and the etching conditions are critical. The primary reference Suguro fails to teach this.

It is submitted the secondary reference Lee et al. fails to supply the missing teachings to achieve or render obvious the claimed invention. The Examiner cites Lee et al. as teaching selectively etching unreacted cobalt film using an etching solution containing hydrochloric acid, hydrogen peroxide and water having a concentration of 1:1:5; etching at a temperature of 20-100° for one minute. Actually, Lee et al. describes two embodiments. One embodiment, a

one-step method, employs a mineral acid:peroxide:water etching solution having a relative concentration ratio of about 1:1:35 to about 1:1:5, with the preferred ratio being about 1:1:15. (See col. 6, lines 40-49). Thus, Lee et al.'s one step etching solution is significantly more dilute than required by Applicant's claims.

For the two-step embodiment, the etching solution in the first step is even more dilute, and has a ratio of about 1:1:300 to about 1:1:70, preferably about 1:1:100. (See col. 6, lines 50-60).

Thus, the etching solutions taught by Lee et al. are significantly more dilute, and only approach the hydrochloric acid concentration required by Applicant's claims, without any overlap. Moreover, this difference is more than merely academic. In Lee et al., the etching solution used in the single-step embodiment removes both the unreacted cobalt and underlying metal nitride. In the two-step embodiment, the etching solution removes unreacted cobalt using the underlying metal nitride as an etch stop; however, in the two-step embodiment, the etching solution is significantly more dilute than that required by Applicant's claims.

The Examiner, on the one hand, acknowledges the primary reference Suguro fails to teach the etching solution of the present invention. However, the Examiner cites Lee et al. as supplying the missing teachings. Lee et al. is concerned with etching different materials, including specifically metal nitride, using different etching solutions. Thus, no combination of Suguro and Lee et al. reasonably could be said to achieve or render obvious Applicant's claim 1, or new claims 2-5 which depend thereon. It is thus submitted the Examiner has employed impermissible hindsight and is applying the teachings of the present invention to the prior art.

Having dealt with all the objections raised by the Examiner, the Application is believed to be in order for allowance.

In the event there are any fee deficiencies or additional fees are payable, please charge them (or credit any overpayment) to our Deposit Account Number 08-1391.

Respectfully submitted,

Norman P. Soloway
Attorney for Applicant
Reg. No. 24,315

CERTIFICATE OF MAILING

I hereby certify that this correspondence is being deposited with the United States Postal Service as First Class Mail in an envelope addressed to: Assistant Commissioner for Patents, Washington, D.C. 20231 on April 22, 2003 at Tucson, Arizona.

By ____________

NPS:nm

HAYES SOLOWAY P.C.

MARKED COPY OF AMENDED SPECIFICATION PARAGRAPHS

SERIAL NO.: 09/940,247

DOCKET: NEC 2360

MARKED SPECIFICATION PARAGRAPHS SHOWING CHANGES MADE

Paragraph beginning at page 1, line 12:

In implementing a high-speed shallow-junction device or mixed DRAM/logic device, the achievement of low-resistivity source and drain electrodes using a salicide (self-aligned silicide) process is essential, and from the standpoint of the fact that the [with] width of lines formed on a substrate is extremely narrow and immunity to heat, cobalt salicide technology is used. In a salicide reaction process, if an impurity for suppressing a silicide reaction exists, local regions occur in which a cobalt silicide region of uniformly low resistivity is not formed.

Paragraph bridging pages 3 and 4, beginning at page 3, line 28:

In the present invention, a cobalt film 6 is formed over the entire surface of a semiconductor substrate 1, onto which [an] a transistor is formed, as shown in Fig. 1 (b) (Step S1). This film is grown at a temperature of 200 to 500°C, using a magnetron sputtering method. Next, this is heat treated for 30 seconds in an inert gas atmosphere, such as nitrogen, at a temperature of 500°C or higher, so as to form a dicobalt silicide film (Co_2Si) , a cobalt monosilicide film (CoSi), and a cobalt disilicide film ($CoSi_2$) thereon (First sinter) (Step S2) . When this is done, the cobalt silicide film 10, as shown in Fig. 1 (c), is formed in self-aligned manner over only the gate electrode 5 and the diffusion layers 3 and 4. Then the semiconductor substrate 1 is immersed in an admixture solution made of hydrochloric acid, hydrogen peroxide, and water (HPM) , so as to perform selective etching, thereby removing unreacted or partially oxidized cobalt from the top of the field oxide film 2 and the side wall film formed on the semiconductor substrate 1 (Fig. 1(d)) . When performing this process of etching away excess cobalt, because to avoid excessive etching of the silicide film on the gate electrode 5 surface,

source and drain regions 3 and 4, it is necessary to optimize the etching conditions, so that the concentration ratios of the hydrochloric acid, hydrogen peroxide, and water are set in the range from 1:1:5 to 3:1:5, the HPM solution temperature is made 25 to 45°C, and the etching time is made 1 to 20 minutes (Step S3) . Next, heat treating at a temperature higher than the first sintering is done, for example, at 800°C for 10 seconds (Fig. 1 (e)) . As a result, a uniform, low-resistivity cobalt disilicide ($CoSi_2$) 11 is formed (Second sinter) (Step S4).

Paragraph bridging pages 5 and 6, beginning at page 5, line 19:

To solve the above-described problem, in a process step for removing unreacted cobalt or a cobalt oxide, it is necessary to reduce the etching rate or to avoid immersion in the etching solution for an excessively long time, thereby only the unreacted cobalt or partially oxidized cobalt film is removed, without influencing the silicide film. In an experiment with the present invention, it was found that the optimum etching is done with an admixture solution made of a hydrochloric acid, hydrogen peroxide, water, the admixture solution having relative concentration ratio ranging from 1:1:5 to 3:1:5, at a solution temperature of 25 to 45°C, with an etching time of 1 to 20 minutes. For example, if etching is done with an etching solution [temperate] temperature of 35°C for an etching time of 3 minutes, only the unreacted cobalt and cobalt oxide are etched, with absolutely no etching of the silicide layer (Fig. 2 (c)) . After this, by performing a second sintering, a uniform, low-resistivity cobalt silicide ($CoSi_2$) film 11 is formed. The occurrence of failures was found to be highly [dependence] dependent on the concentration and temperature of the etching solution, and the etching time.

Paragraph bridging pages 6 and 7, beginning at page 6, line 21:

First, a cobalt film 6 is formed over the entire surface of a semiconductor substrate 1,

onto which a transistor is formed, as shown in Fig. 3 (b) . After the cobalt film 6 is formed, a titanium (Ti) or titanium nitride (TiN) film 7 is formed so as to cover the cobalt film 6 and prevent the oxidation thereof (Fig. 3 (c)) . The method of forming these [film] films is either a magnetron sputtering method or vapor deposition. In this condition, heat treating is done in an inert gas atmosphere for 10 to 60 seconds at a temperature of 500°C or higher, so as to form a dicobalt silicide film, a cobalt monosilicide film, or a cobalt disilicide film (First sintering) . When this is done, the cobalt silicide film 10 is formed in self-aligning manner over only the gate electrode 5 and the diffusion layers 3 and 4 (Fig. 4 (a)). Next, in order to remove the titanium or titanium nitride film 7 formed as a cap film to prevent oxidation of the cobalt film 6, the silicon substrate 1 is immersed in an admixture solution made of ammonia, hydrogen peroxide, and water (APM) (Fig. 4 (b)). After this is done, the silicon substrate 1 is immersed in an admixture solution of hydrochloric acid, hydrogen peroxide, and water (HPM) , so as to remove only the unreacted cobalt or partially oxidized cobalt from the field oxide film 2 and the side wall film 12 by selective etching (Fig. 4 (c)). When this is done, in order to avoid etching of the silicide film formed on the source and drain regions 3 and 4 and the gate electrode 5 by excessive etching, the etching conditions used are a relative concentration ratio of hydrochloric acid, hydrogen peroxide, and water in the range from 1:1:5 to 3:1:5, an HPM solution temperature in the range from 25 to 45°C, and an etching time of 1 to 20 minutes. Next, heat treating is done for 10 to 60 seconds at a temperature higher than that of the first sintering (Fig. 4 (d)) . As a result, a uniform, low-resistivity cobalt disilicide film 11 is formed.

MARKED COPY OF AMENDED CLAIM 1

SERIAL NO. 09/940,247

DOCKET: NEC 2360

MARKED AMENDED CLAIM SHOWING CHANGES MADE:

1. (Amended) A method for forming a metal silicide layer in a self-aligned manner on a source region, a drain region and a gate electrode of a semiconductor device formed on a semiconductor substrate, said method comprising the steps of:

(A) depositing a cobalt film over an entire surface of said semiconductor device formed on said semiconductor substrate,

(B) forming [said] a metal silicide layer on said source region, drain region and said gate electrode by performing a heat treating thereof, and

(C) etching away an unreacted cobalt film remaining on said semiconductor substrate while leaving the metal silicide layer intact, using as an etching solution an admixture solution made of hydrochloric acid, hydrogen peroxide, and water, having relative concentration ratio thereof ranging from 1:1:5 to 3:1:5, at a solution temperature of 25 to 45°C, with an etching time of 1 to 20 minutes.

MARKED COPY OF DRAWINGS

SERIAL NO.: 09/940,247

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